#4

PATENT

Agent's Docket No. **12917-US**

OIPE JC98 MAY 2 0 2002 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	)	
	)	
JIN, Gary Q.	)	
	)	
Serial No: **10/085,061**	)	Art Unit: **2631**
	)	
Filed: **March 1, 2002**	)	Examiner:
	)	

For: **DMT PEAK REDUCTION WITHOUT AFFECTING TRANSMISSION SIGNAL**

May 14, 2002

Commissioner of Patent and Trademarks

Washington, D.C. 20231

RECEIVED
MAY 2 1 2002
Technology Center 2600

TRANSMITTAL LETTER

Sir:

Submitted herewith are the following documents:

- Transmittal Letter (in duplicate)
- Certified copy of Priority Document (British Application No. 0105185.3)

Respectfully submitted,

BY: [signature]

Richard J. Mitchell
Reg. No. 34,519
Agent of Record

MARKS & CLERK
P. O. Box 957, Station B
Ottawa, Ontario Canada K1P 5S7 (613) 236-9561

THIS PAGE BLANK (USPTO)

MAY 2 0 2002
JC98
PATENT & TRADEMARK OFFICE

TRANSMITTAL LETTER (General - Patent Pending)	Docket No. 12917-US

In Re Application Of:

JIN, Gary Q.

Serial No.	Filing Date	Examiner	Group Art Unit
10/085,061	March 1, 2002		2631

Title:

DMT Peak Reduction Without Affecting Transmission Signal

TO THE COMMISSIONER OF PATENTS AND TRADEMARKS:

Transmitted herewith is:

Certified Copy of Priority Document, British Patent Application No. 0105185.3, filed March 2, 2001

RECEIVED
MAY 2 1 2002
Technology Center 2600

in the above identified application.

- ☒ No additional fee is required.
- ☐ A check in the amount of is attached.
- ☐ The Commissioner is hereby authorized to charge and credit Deposit Account No. as described below. A duplicate copy of this sheet is enclosed.
  - ☐ Charge the amount of
  - ☐ Credit any overpayment.
  - ☐ Charge any additional fee required.

Signature

Dated: May 14, 2002

Richard J. Mitchell 34,519
MARKS & CLERK
P.O. Box 957
Station B
Ottawa, ON
K1P 5S7 CANADA
Tel: (613)236-9561

I certify that this document and fee is being deposited on with the U.S. Postal Service as first class mail under 37 C.F.R. 1.8 and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Signature of Person Mailing Correspondence

Typed or Printed Name of Person Mailing Correspondence

cc:

MAY 20 2002

PATENT & TRADEMARK OFFICE

The Patent Office

PATENTS • DESIGNS • COPYRIGHT • TRADE MARKS

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed Stephen Hordley

Dated 13 March 2002

CERTIFIED COPY OF PRIORITY DOCUMENT

Patents Form 1/77

Patents Act 1977
(Rule 16)

The Patent Office

THE PATENT OFFICE
A
02 MAR 2001
NEWPORT

1/77

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

1. Your reference	RPH.P51508GB	02MAR01 E610424-5 D01063 F01/7700 0.00-0105185.3
2. Patent application number *(The Patent Office will fill in this part)*	02 MAR 2001	0105185.3
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Mitel Corporation 350 Legget Drive PO Box 13089 Kanata, Ontario K2K 2W7, Canada	
Patents ADP number *(if you know it)*		60763006
If the applicant is a corporate body, give the country/state of its incorporation	Canada	
4. Title of the invention	"DMT Peak Reduction without Affecting Transmission Signal"	
5. Name of your agent *(if you have one)*	Marks & Clerk	
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	4220 Nash Court Oxford Business Park South Oxford OX4 2RU	
Patents ADP number *(if you know it)*	7271125001	

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	0
Description	6
Claim(s)	3
Abstract	1
Drawing(s)	1 +1

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Marks & Clerk Date
Marks & Clerk 1 March 2001

12. Name and daytime telephone number of person to contact in the United Kingdom

Richard Harding - 01865 397900

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

DMT PEAK REDUCTION WITHOUT AFFECTING TRANSMISSION SIGNAL

FIELD OF INVENTION

This invention relates to the field of data communication, and in particular to a method of reducing signal peaks in a Discrete Multitone (DMT) signal.

BACKGROUND OF THE INVENTION

DMT or Discrete Multitone is a multicarrier transmission technique that uses a Fast Fourier Transform (FFT) and inverse FFT to allocate transmitted bits among many narrow narrowband QAM modulated tones depending on the transport capacity of each tone. This of course can vary with transmission conditions. As is known in the art, QAM (Quadrature Amplitude Modulation) is a passband modulation technique wherein information is represented as changes in carrier phase and amplitude.

DSL or Digital Subscriber Line is a system wherein a non-loaded local loop provides a copper connection between a network service provider and customer premises. DMT is a common form of modulation used in DSL systems. In a DMT based DSL system, the required peak-to average ration (PAR) of a signal is 15 dB for the probability of a clipping occurring to be 10^{-8} (assuming a Gaussian distribution).

A large PAR value will seriously reduce the signal dynamic range. On the one hand, any peak value will cause signal saturation and the error will spread at all frequency subcarriers. In the worst case, the entire frame of a signal can be wiped out. On the other hand, if the PAR is increased so that the signal has less chance of being clipped, the dynamic range is lost. For the case where PAR=15 dB, the signal will normally be transmitted 15 dB below its peak level.

In a DMT system, multiple QAM constellations are modulated on different carrier frequencies. In the time domain, the signal has variable levels. Normally, the maximum peak-to-average ratio ranges from 27 dB to 39 dB depending on the size of FFT. To increase the signal dynamic range and reduce the PAR, several methods have been used in DMT based DSL systems. The most efficient method is to use a special waveform known as a signature waveform. This is a time domain signal which has a large peak in it and is otherwise small at other time instants. Whenever the signal is larger than a maximum

level, the signature waveform is subtracted from the signal so that the signal will not be saturated. However, addition of the signature waveform will generally cause distortion to the transmission signal.

Prior art peak reduction systems are described, for example,, in J.Tellado and J.Cioffi, "PAR Reduction in Multicarrier Transmission System", ANSI Contribution T1E1.4/97-367, Sacramento, CA, December 1997; and A.Gatherer and M.Polley, "Controlling Clipping Probability in DMT Transmission", 1997 Asilomar Conference, Nov., 1997, the contents of which are herein incorporated by reference.

An object of the invention is to alleviate this problem.

SUMMARY OF THE INVENTION

The invention provides a signature waveform which introduces no or minimum signal distortion. The signature waveform is designed so that whenever the signal is above a maximum level, the signature waveform is subtracted from the signal peak position. As a result, the signal will not be saturated. The advantages such a signature waveform design are that the PAR can be reduced by as much as 6 dB, and no distortion is introduced into the transmission signal. The transmission signal has no distortion after peak deduction.

Accordingly the present invention provides a method of effecting peak reduction in a DMT signal, comprising the steps of creating a predetermined signature waveform, and subtracting said predetermined signature waveform from said DMT signal in the region of a signal peak whenever the DMT signal is above a predetermined maximum level.

In a preferred embodiment the signature waveform is generated by an iterative process from a predetermined starting waveform and passing it through time domain and frequency domain restriction units.

Typically the signature waveform is aligned with the time domain DMT output signal and multiplied by a scaling factor derived from the maximal value of the time domain DMT output signal. The result is passed through a bit shifter to match the number bits per sample of the result with the number of bits in the samples of the time domain DMT signal.

The invention also provides an arrangement for effecting peak reduction in a DMT signal, comprising a first circuit for creating a predetermined signature waveform, and a second circuit for subtracting said predetermined signature waveform from said DMT signal in the region of a signal peak whenever the DMT signal is above a predetermined maximum level

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows one embodiment of a circuit for reducing the PAR of a signal; and

Figure 2 is a block diagram illustrating the calculation of a signature waveform.

DETAILED DESCRIPTION OF THE INVENTION

As noted above, the object of the invention is to reduce the PAR (Peak-to-average ratio) of a signal to be transmitted. In accordance with the principles of the invention this is achieved by subtracting the signature waveform from the signal whenever the signal is above a predetermined maximum level. As a result, the signal will not be saturated.

The invention uses a few bits and a short vector for the signature waveform so that both the memory and computation requirements are minimized. Also, by carefully choosing the value *C*, as defined below, it is possible to achieve the maximum PAR reduction by 6 dB and maintain minimum signal distortion. The signature waveform s(k) is represented by a 256 byte vector (256 x 8 bits) with a maximal value of 0x 7f (0x indicates hexadecimal notation, so, for example, 7f would be 01111111 in binary notation).

Referring now to Figure 1, a practical implementation of the invention comprises an IFFT (Inverse FAST Fourier Transform) unit 100 which receives a frequency modulated DMT input signal X and outputs an IFFT time domain signal $x(k_1)$, which is represented as 16 bit numbers. The output signal $x(k_1)$ is fed to a subtractor 101.

In the meantime, the IFFT 100 unit calculates the maximal value of the amplitude (M) in a DMT frame. If the absolute maximal value (|M|) of the time domain signal ($x(k_1)$) is smaller than 0x08000, no action is required for PAR reduction, and the comparison output

C is set to zero. Otherwise, if the maximal value (|M|) is equal to or greater than 0x08000, the threshold calculator 102 outputs the address location of the maximal value (I) in the series of samples and carries out the following steps:

If |M| is larger than 0x0FFFF, |M| is first saturated to a predetermined maximal value 0x0FFFF.

While the signature waveform is to be subtracted from the signal ($x(k_1)$), it must first be aligned with the signal peak bearing in mind that the signature waveform is only 256 bytes long. It must also be remembered that the signature waveform consists of only 8 bit samples whereas the signal consists of 16 bit samples.

Alignment of the signature waveform with the peak is achieved by taking IFFT output samples at addresses k_1 ranging from [I-128:I+127] (before the prefix, suffix and window are added), and subtracting the signature waveform multiplied by a suitable scaling factor C where C is determined as follows:.

$$|M| - ((C \times (0x0080)) \gg 7) = 0x08000$$

$$C = (|M| - 0x08000) \times \mathrm{sgn}(M)$$

The address k_1 for IFFT output x should be cyclically extended, i.e., if $k_1<0$, the true address should be k_1+N, where N is number of FFT points (For a normal DMT based DSL system, N=512, 1024, 2048, 4096 and 8192), and if k1>N-1, the true address should be k1-N.

The signature waveform s(k), which consists of 8 bits samples, is then multiplied by the scaling factor C, which consists of 16 bits samples, in multiplier 103. The result is a 23 bit number which is shifted 7 bits to the right in unit 104 to give a 16 bit number that is subtracted from $x(k_1)$ in subtractor 101.

The creation of the signature waveform is performed as shown in Figure 2. The signature waveform calculation is shown in Fig.2. First an initial frequency waveform is selected and the frequency domain signal passed through and IFFT 201 to produce a time domain signature waveform s(n). This signal is then checked with a required threshold in unit 202 and any time domain samples which are above threshold are corrected to produce a

modified time domain signal $s_1(n)$. This signal is passed through FFT unit 203 to produce a frequency domain waveform S(k).

This signal S(k) is then checked against a required frequency mask in unit 204 and any signals that are above the mask are corrected to comply with the mask requirements. The output of $S_1(k)$ of unit 204 is passed back into the IFFT 201 and the process repeated on an iterative basis unit either the waveform change becomes insignificant between successive iterations or a maximum number of iterations is reached.

An example of a time domain threshold for unit 202 is:

$$s_1(n) = \begin{cases} 1, & n=128; \\ s(n), & |s_1(n)| \le 0.5, n \ne 128 \\ 0.5 \times \mathrm{sgn}(s(n)), & |s_1(n)| > 0.5, n \ne 128 \end{cases}$$

In the above equation, it is assumed that the center point of the signature waveform is centered at n=128 and the threshold is a constant 0.5.

An example of frequency domain mask for unit 204 is:

$$S_1(k) = \begin{cases} S(k), & \text{k is in region 1 or small than required threshold} \\ \gamma_1 \times \mathrm{sgn}(S_1(k)), & \text{k is in region 2 and } |S_1(k)| > \gamma_1 \\ \gamma_2(k) \times \mathrm{sgn}(S_1(k)), & \text{k is in region 3 and } |S_1(k)| > \gamma_2 \end{cases}$$

Here, the region 1 belongs to transmitter frequency band which is not used. This band can be used for signature waveform with no constraints. The region 2 belongs to the receiver frequency band and the corresponding threshold γ_1 is set such that it is equal to the required transmitter spectrum mask for the receive band, or in case there is no restriction on the transmit signal on the receiver band, γ_1 is set such that the generated echo signal to

the receiver band is smaller than the requirement. The region 3 belongs to the transmitter band where data bits are modulated and $\gamma_2(k)$ is set as the 1/6 to 1/4 of the constellation distance which differs for different frequency subcarriers (k).

The above threshold selection will ensure that the signature waveform uses all possible frequency bands so that it can best approach an impulse function. At the same time, it will not violate any frequency requirements and will cause no signal distortion to both the far end and the near end receivers.

The invention provides an effective implementation for PAR reduction. The signature waveform design is such that it best approaches the impulse function and at the same time causes no or minimal distortion to both the transmitter and receiver signals.

The method described can be implemented with small amount of memory and fewer computations. By employing suitable parameters, the PAR reduction can be maximized.

The iterative method for the signature waveform creation ensures an optimal choice for the signature waveform. All possible frequency band are employed to create the optimum signature waveform.

Claims:

1. A method of effecting peak reduction in a DMT signal, comprising the steps of creating a predetermined signature waveform, and subtracting said predetermined signature waveform from said DMT signal in the region of a signal peak whenever the DMT signal is above a predetermined maximum level.

2. A method as claimed in claim 1, wherein said DMT signal is first passed through an IFFT unit which produces a time domain signal $x(k_1)$.

3. A method as claimed in claim 2, wherein said IFFT unit generates a first output M representing a maximal value of said signal $x(k_1)$ and a second output I representing the address location of the maximal value I in said signal $x(k_1)$.

4. A method as claimed in claim 3, wherein said predetermined signature waveform is subtracted from said DMT signal when the absolute value $|M|$ is above a predetermined value.

5. A method as claimed in claim 4, wherein said signature waveform has fewer samples than said DMT signal, and said signature waveform is first aligned with said signal peak prior to subtraction.

6. A method as claimed in claim 5, wherein said signature waveform is first multiplied by a scaling factor to match said DMT signal.

7. A method as claimed in claim 6, wherein said scaling factor is determined from said absolute value $|M|$.

8. A method as claimed in claim 7, wherein the scaling factor C is determined in accordance with the equation

$$C = (|M|) - 0xXXXXX) \times sgn(M)$$

where 0xXXXXX is a predetermined number.

9. A method as claimed in claim 7, wherein the result of multiplying the scaling factor with said signature waveform is first shifted to match the number of bits per sample in the result with the number of bits representing the time domain signal $x(k_1)$.

10. A method as claimed in any one of claims 1 to 9, wherein said signature waveform is generated by passing a predetermined waveform through a waveform modifying circuit on an iterative basis until the waveform change is insignificant between samples or a maximum number of iterations is reached.

11. A method as claimed in claim 10, wherein said waveform modifying circuit comprises an IFFT unit to produce said signature waveform s(n) in the time domain, a waveform restriction unit to produce a modified time domain signature waveform signal $s_1(n)$, and FFT unit to produce a frequency domain modified waveform signal S(k) and a spectrum restriction unit to produce a band limited frequency signal $S_1(k)$ which is passed back to said IFFT unit as part of said iterative process.

12. An arrangement for effecting peak reduction in a DMT signal, comprising a first unit for creating a predetermined signature waveform, and a second unit for subtracting said predetermined signature waveform from said DMT signal in the region of a signal peak whenever the DMT signal is above a predetermined maximum level.

13. An arrangement as claimed in claim 12, wherein said second unit comprises an IFFT unit for generating a time domain signal from said DMT signal which is applied to a subtractor.

14. An arrangement as claimed in claim 13, wherein said IFFT unit has two additional outputs representing respectively the maximal value and location of said maximum value in said DMT signal.

15. An arrangement as claimed in claim 14, wherein said additional outputs a applied to respective inputs of a threshold calculation unit that generates a scaling factor for said signature waveform when said absolute value is above a predetermined value.

16. An arrangement as claimed in claim 15, wherein said first unit comprises an IFFT unit for generating a time domain signal from a predetermined input waveform, a time domain waveform restriction unit, an FFT unit for producing a modified frequency domain waveform, and a spectrum limiting unit for said modified frequency domain waveform, an output of said spectrum limiting unit being applied to an input of said IFFT unit to permit generation of said signature waveform by means of an iterative process.

17. A method of effecting peak reduction in a DMT signal, substantially as hereinbefore described with reference to the accompany drawings.

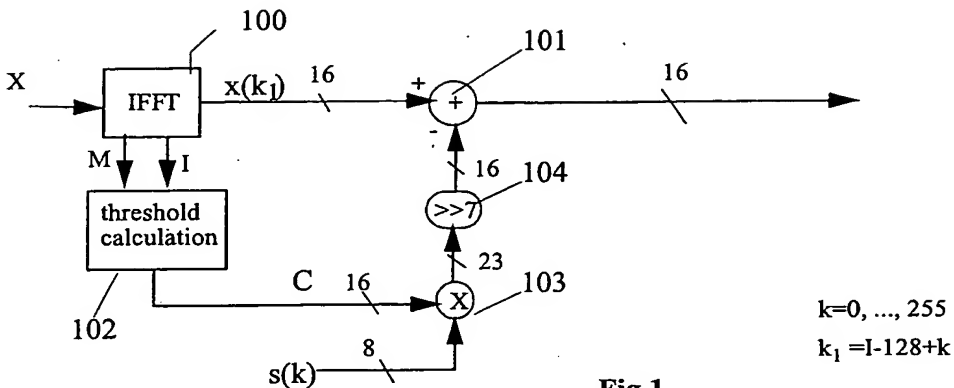
18. An arrangement for effecting peak reduction in a DMT signal, substantially as hereinbefore described with reference to the accompany drawings.

ABSTRACT OF THE DISCLOSURE

In a method of effecting peak reduction in a DMT signal, a predetermined signature waveform is first produced. This is then subtracted from the DMT signal in the region of a signal peak whenever the DMT signal is above a predetermined maximum level.

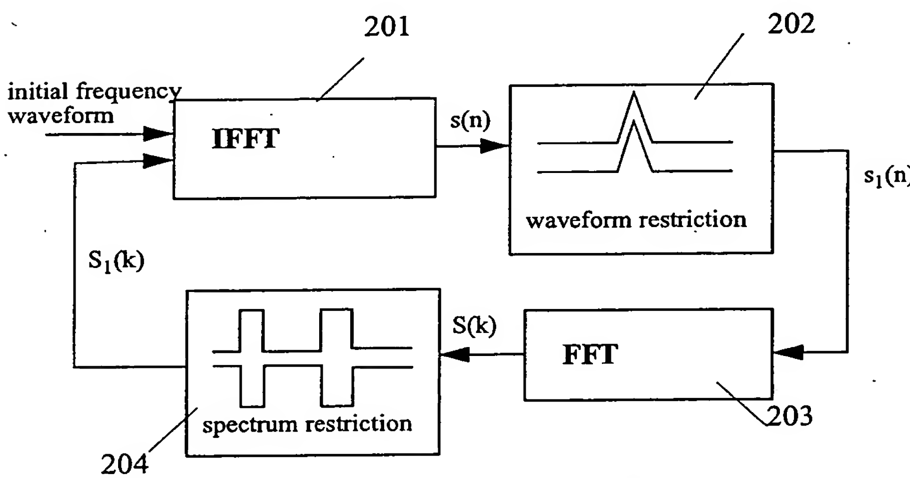
(Figure 1)

1/1



100
X
IFFT
x(k1)
16
+
101
16
-
M
I
16
104
threshold calculation
>>7
23
C
16
X
103
102
8
s(k)
k=0, ..., 255
k1 =I-128+k

Fig.1



201
202
initial frequency waveform
IFFT
s(n)
waveform restriction
s1(n)
S1(k)
S(k)
FFT
spectrum restriction
203
204

Fig. 2

THIS PAGE BLANK (USPTO)

RECEIVED
MAY 23 2002
OIPE/JCWS